DME for Power Generation Fuel: Supplying India's Southern Region

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Abstract

BP and Haldor Topsøe A/S (Topsøe) have jointly pursued the application of DME as a clean fuel since the mid-nineties -- BP as a major energy company with a global gas strategy to supplying power generation plants and clean fuels, and Topsøe as developer of a new technology to produce DME in large quantities at competitive cost. BP has identified India as a promising market for DME and formed a partnership with Indian Oil Corporation Limited (IOCL), the Gas Authority of India Limited (GAIL), and the Indian Institute of Petroleum (IIP) to pursue the application of DME in India. This paper focuses on the (1) infrastructure and logistics required to supply select states in southern India with DME including DME Manufacturing, Shipping, and Offloading/Receiving Terminal, and (2) the collaborative efforts with Snamprogetti to economically manufacture DME – a key to competitively priced DME.

Key Words

Dimethyl ether, DME, power, fuel, BP, Topsøe, Snamprogetti, IOCL, GAIL, IIP

Background

Recognizing that DME can be a new economical fuel for the 21st century, India's Ministry of Petroleum and Natural Gas invited BP in 1997 to develop DME supplies in an exclusive partnership with India's leading energy marketers and research organization; Indian Oil Corporation Limited (IOCL), the Gas Authority of India Limited (GAIL) and the Indian Institute of Petroleum (IIP). In July 1998, BP signed a commercial and technical agreement (Joint Collaboration Agreement) with IOCL, GAIL and IIP to collaborate in the development, production and marketing of DME as a multi-purpose fuel for India.

At the Petrotech-99 Conference, R. Puri, et.al. presented a paper entitled, "DME: Competitive Advantages as a Fuel for India, (Sl. No. T258). This paper presented how DME is a multi-application fuel that can fuel India's growing demand for electric power. More information on the India DME Project will be presented in other papers presented at the conference. Another source of information can be found at the internet website for the India DME Project: http://www.dmeforpower.com/.

DME marketing has focused on the four southern states (Andhra-Pradesh, Tamil Nadu, Kerala and Karnataka). Seven power projects/plants with an aggregate demand of over 2.5 GW have signed Memoranda of Understandings expressing their interest in purchasing DME as a substitute for naphtha and diesel. This paper describes the infrastructure and logistics required to supply these power projects/plants with DME. This description includes DME Manufacturing, Shipping, Offloading/Receiving Terminal, as well as a list of the collaborative efforts that resulted in competitively-priced DME. (reason for change: repetition from abstract)

DME Supply Chain

DME serves a different market segment than LNG but the supply chain is similar, with dedicated customers, although the scale is smaller. The DME supply chain consists of gas production, manufacturing, shipping, storage, and marketing to customers. The potential gas supply for making DME would most likely be in the Middle East/Gulf Region. Other sources could be the northwest shelf of Australia, and Indonesia.

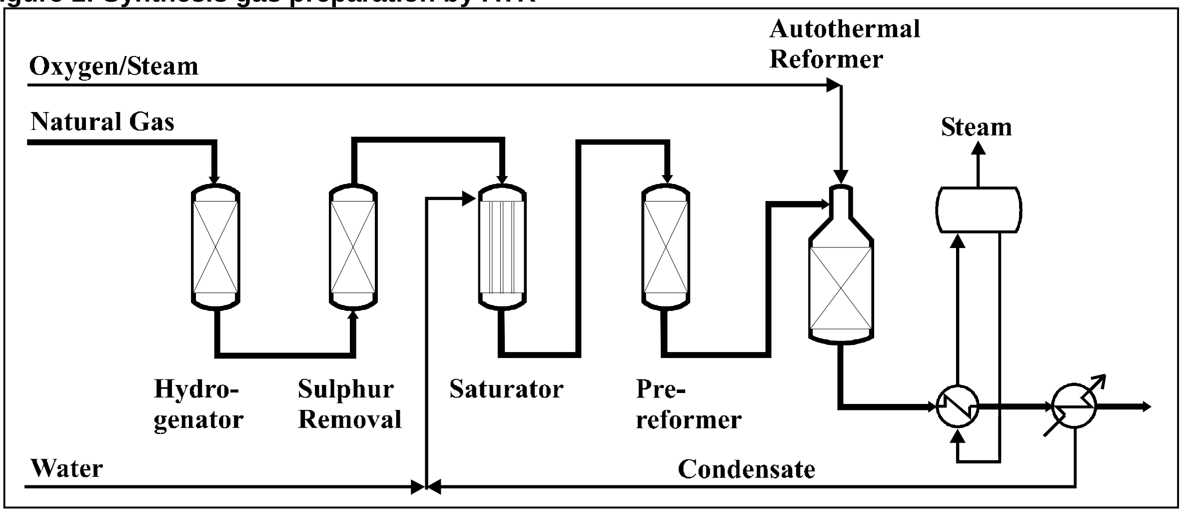
How DME is Made – The Topsøe Technology for Production of DME

The Topsøe process for direct synthesis of DME combines in a single plant the production of methanol directly from natural gas and the subsequent conversion into DME in one integrated synthesis section. This process layout eliminates the need to isolate and purify methanol as an intermediate before further processing into DME.

The Topsøe DME process is based on well-proven technology and process scheme, similar to the one used for producing methanol. The plant comprises 3 process sections, viz.:

Synthesis gas preparation by AutoThermal Reforming (ATR)
Oxygenate synthesis (combined synthesis of methanol and DME)
Product separation and purification

Figure 1: Synthesis gas preparation by ATR



Production of liquid fuels from natural gas requires very large capacities in order to benefit from economy of scale to the maximum degree. The most suitable reforming technology for this purpose is the Topsøe ATR technology, which permits single line production units exceeding 7,500 MTPD DME.

The Topsøe ATR technology has been developed tremendously over the last decade, and recently it has been demonstrated industrially at a steam/carbon ratio of only 0.6[1] The synthesis gas preparation section of the plant is shown in figure 1. As illustrated, the plant layout is similar to a conventional reforming section, with the exception of the very low steam/carbon ratio. The basis for the unique position of Topsøe with respect to autothermal reforming is the development 10 years ago of the CTS burner[2]. The CTS

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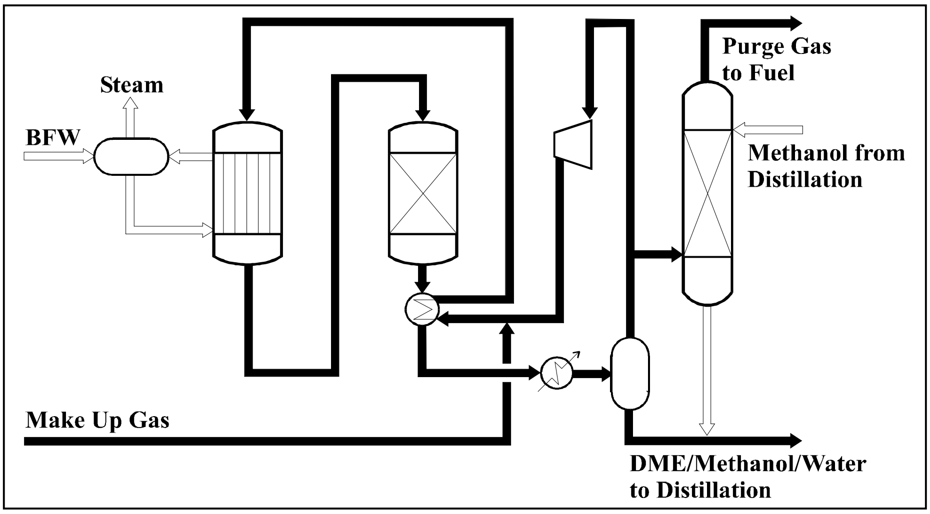
[1] Hydrocarbon processing March 2000, p 100

[2] Burners for Secondary and Autothermal Reforming – Design and Industrial Performance", T. S. Christensen, I. Dybkjær, L. Hansen and I. I. Primdahl, Haldor Topsoe A/S, Presented at AIChE Ammonia Safety Symposium, Vancouver, October 1994.

burner has been a radical commercial success, and it is found today in the vast majority of oxygen blown ATR's worldwide.

Combined synthesis of methanol and DME –
The oxygenate synthesis takes place in a synthesis loop consisting of two reactor stages over a combination of methanol and dual function catalysts. The synthesis section layout is illustrated in figure 2.

Figure 2: DME synthesis



The reaction from synthesis gas to DME is a sequential reaction, involving methanol as an intermediate. The first part of the reaction from synthesis gas to methanol is quite exothermal and it is limited by equilibrium at a fairly low temperature. Therefore, the first part of the reaction takes place in a cooled reactor where the reaction heat is continuously removed, and the equilibrium is approached at optimum conditions.
The second part of the reaction from methanol to DME is much less exothermal, and the equilibrium is limited at a higher temperature. Therefore, this part of the reaction takes place in an adiabatic fixed bed reactor.

Consequently, the two-stage reactor concept permits both parts of the sequential reaction to take place at optimum conditions, while at the same time the synthesis section becomes more similar to a conventional methanol synthesis loop.
The only major difference between the oxygenate synthesis and the methanol synthesis is the second stage adiabatic reactor, loaded with the proprietary Topsøe dual-function catalyst. This dual-function catalyst is a unique development made in the early 1990's. Since then this catalyst has been tested in excess of 30,000 hours in a Topsøe DME process demonstration unit. Due to the extensive catalyst testing and the simple adiabatic reactor configuration, the technology risk in the DME synthesis is minimal.

Product separation and purification –
The layout of the separation and purification section depends on the specific demands for product purity. Obviously, the lower demands for product purity, the lower investment and energy consumption. In fact, substantial savings are achieved by producing fuel grade DME, i.e. DME containing minor amounts of methanol and water.

From a reference point of view, the direct DME purification section may be considered as a combination of a methanol distillation section and the purification section of a conventional DME plant based on methanol dehydration.

Fuel Grade DME for power generation will be a blend of DME plus water, methanol and other minor oxygenates. This is due to economies in the manufacturing process and the

Table 1 Fuel Grade DME Specification

	Range Wt. %
Water	3.2 ± 0.3
Methanol	7.5 ± 1.0
DME	88.9 ± 0.9
Oxygenates, high Ethers & Gases	0.4 ± 0.1
Metals, Nitrogen, and Sulfur	Nil

incremental benefits associated with the blend of methanol and water. The range of technical specifications of the fuel grade DME are shown in Table 1 and the physical properties are illustrated in Table 2.

Table 2 Fuel Grade DME Physical Properties

	Metric units	Imperial units
Liquid Density @ -25°C	0.7458 ton/m^3	46.56 lb/ft^3
High Heating Value as a Liquid	7,152 kcal/kg	28.38 MM BTU/ton
Low Heating Value as a Liquid	6,449 kcal/kg	25.75 MM BTU/ton
Low Heating Value as a Gas	6,636 kcal/kg or 11,986 kcal/m^3	1,347 btu/ ft^3

How is DME Shipped, Offloaded, Stored, and Delivered to Power Plants

DME is physically similar to liquefied petroleum gas (LPG). The properties of DME are compared with those of propane and butane, the two main components of LPG in Table 3.

Table 3 - Properties of DME Compared with Propane and Butane

Property	DME*	Propane	Butane
Boiling Point, °C	-24.9	-42.1	-0.5
Vapor Pressure @ 20 °C, bar	5.1	8.4	2.1
Liquid Density, @ 20 °C , kg/m3	668	501	610
Specific density, gas	1.59	1.52	2.01
Lower Heating Value, kJ/kg	28,430	46,360	45,740
Ignition Temperature @ 1 atm, °C	235-350	470	365
Explosion/Flammability Limit in air, vol %	3.4-17	2.1-9.4	1.9-8.4

* The properties of Fuel Grade DME will differ from neat DME depending on the amount and type of other oxygenates, and water.

Since DME has physical characteristics similar to LPG, it can take advantage of the vast experience and mature technologies available for LPG handling.

Ocean transport of DME can use conventional LPG tankers. The distance from the Middle East could vary from say under 2000 nautical miles to Cochin, on India's west coast, to about 3000 miles to Kakinada, on the east coast.

DME can be offloaded and stored at a receiving location using the same conventional LPG-type unloading and storage equipment. DME, like LPG, can be stored onshore in either a pressurized, semi-pressurized, or refrigerated condition.

With respect to DME shipping, this product can be carried in LPG tankers that have been altered for this cargo. Some gaskets and pump seals may need to be changed. While LPG vessels come in many sizes and types (pressurized, semi refrigerated, and refrigerated). It would only be worthwhile to consider two or three sizes of the refrigerated type. These are vessels in about the 35,000; 54,000; and 78,000 cubic meter sizes.

As the project ports are identified, further in-depth research of the actual port conditions of the specific area will form the basis for the decision on the best ship size for the project. Additionally there may be specific vessel size (this could be due to vessel length, beam, deadweight, displacement or type) restrictions due to harbor/dock size, turning circle size, or other restrictions.

Some of the things to discuss with the port authorities, facility operators, shipping agents, or other members of the shipping community include: Port restrictions such as draft, channel restrictions (width, transit restrictions, type of bottom -- mud or rock), daylight only navigation, navigational buoys, tides and tidal currents, normal and severe weather restrictions. Additionally, there may be specific vessel size (this could be due to vessel length, beam, deadweight, displacement or type) restrictions due to harbor/dock size, turning circle size, or other restrictions.

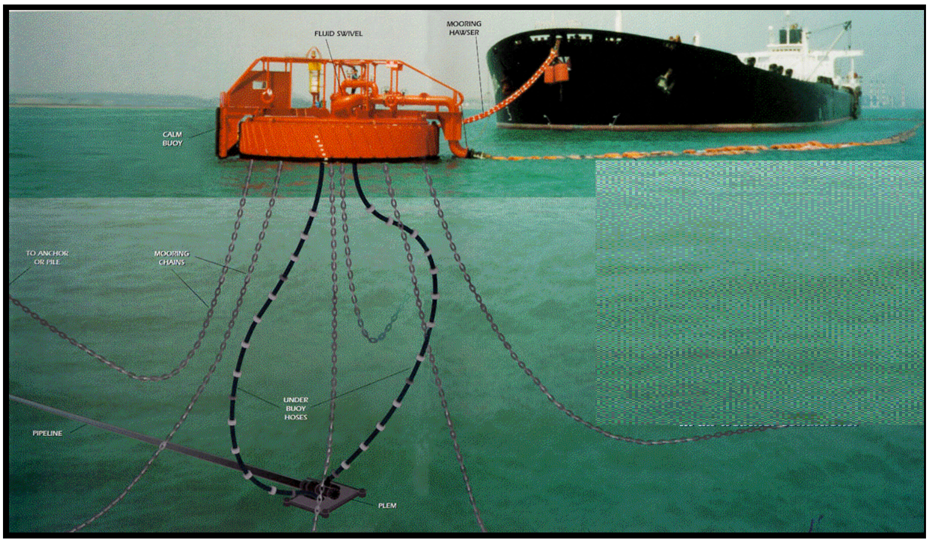
DME Offloading and Onshore/Receiving Terminal

Conventional offloading at LPG ports

The DME receiving and unloading facilities would be designed to receive and unload a 35,000 – 78,000 m3 DME shipment. Loading arms are provided to transfer the DME from the tanker to the insulated DME storage tanks. After the loading arms are connected to the tanker's manifold, the tanker's pumps are used to transfer the DME to the storage through insulated pipelines. The DME is unloaded at about -25^{o}C.

Single Point Mooring System

Figure 3: DME Off-loading by Single Point Mooring



An alternative design for unloading DME and supplying nearby power plants is the Single Point Mooring System (SPM) design that utilizes a cantenary anchor mooring system for DME off-loading, as shown in figure 3, without the need for a port.

Single Point Mooring (SPM) allows for a tanker vessel to take the line of least resistance to the loads imposed by wind, wave and current, by being able to weathervane about the mooring point. This weathervaning feature allows for the mooring of tankers in open i.e., unprotected, water so there is no need to construct jetties and breakwaters. DME is transported onshore via insulated submarine pipeline.

Both alternatives would include on-shore port infrastructure for DME receiving and storage facilities, and pipelines to deliver liquid DME to power plants. The DME storage tanks are maintained at a pressure of 1 psig and a corresponding temperature of -25^{o}C. Necessary utilities include relief valves, flare header, instrument and plant air, firewater and fire protection systems, potable and utility water, nitrogen and emergency power generator.

Competitively Priced DME Requires Prudent Capital Investment

A key to commercial success is for the project to supply DME at a price competitive with other fuels that the power plant can use, such as naphtha, diesel or LNG, while providing a reasonable return of investment. To meet this criteria, all costs in the supply chain, including gas supply, manufacturing plant, shipping and receiving terminal, need to be minimized. Considerations to minimize the costs for the DME manufacturing and offloading/receiving terminal will be discussed in this section. Other important components of the price that will not be covered here include custom duties, state/local taxes and financial terms. The gas supply cost and shipping costs depend on the resource supply and distance from the supply to the market, respectively.

DME Manufacturing Plant Cost

DME is traditionally produced on a small scale by fixed bed catalytic dehydration of methanol. In this case its production cost are intrinsically higher than that of methanol. Large-scale manufacture of DME by direct synthesis from natural gas on a single train allows significant savings in investment and production cost due to higher process efficiency and better economy of scale, thereby making DME use as fuel economically attractive.

Effective collaboration between Topsøe, Snamprogetti and BP has resulted in an optimized low-cost design that represents significant savings in both capital cost and operating costs. Key results of this collaboration are:

- A base case plant design for a grassroots plant located in the Middle East that produces 5,000 MTPD Fuel Grade DME. This design includes: (1) an optimum design for Synthesis Gas Preparation section particularly having a low steam/carbon ratio, (2) a two–stage Oxygenate Synthesis section that allows reactions at optimum conditions, and (3) effective heat integration.
- Product composition that takes advantage of the process chemistry and the fuel specifications for power generation rather than the more-stringent chemical specifications for DME used as aerosol propellants.
- Cost estimate from an experienced, international engineering and construction contractor.

DME Offloading/Receiving Terminal Cost

Key to low cost delivery of DME from tankers to an onshore terminal, if an existing conventional port is not available, is to use leading-edge SPM technology for offloading refrigerated DME. A recent study showed that the cost of SPM, excluding the insulated submarine pipeline, could be less than 20% of the cost of a grassroots port that included dredging and jetty/breakwaters. The key to low-cost insulated submarine pipeline is to minimize the distance from the SPM location to the onshore facilities.

Potential cost savings in the onshore receiving terminal include minimizing the refrigerated storage volume, selecting a site with sufficient civil data for borings if needed and requiring minimal site improvements, and having options for sharing infrastructure costs such as steam, fire fighting, water treatment and emergency power with nearby facilities. Other significant cost issues include the impact of weather conditions and environmental impact assessment, and the availability of water.

Other Costs

The gas supply cost and shipping costs depend on the resource supply and distance from the supply to the market, respectively. The group behind the India DME Project (BP, IOCL, GAIL and IIP) is moving forward to secure a gas supply. The DME Consortium is currently opening negotiations with gas resource holders for gas supply and the location for the manufacturing plant. Also, the DME Group is seeking cooperation/participation by companies who can add value to the project such as shippers to economically ship DME, and EPC contractors to build the offloading/receiving terminal.

Conclusions

Fuel Grade DME can be supplied to south India as a competitively-priced fuel for power generation. DME could be produced in the Middle East at the site of the gas resource using Topsøe technology; shipped 2000-3000 nautical miles to south India; and offloaded/stored utilizing LPG experience/technology. Collaborative efforts of BP, IOCL, GAIL, IIP, Topsøe and Snamprogetti have provided the details that show that DME as a fuel for power generation in India can be a viable business.